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AUTHOR Tasker, Ross; And Others
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ABSTRACT

The first (exploratory) phase of the Learning in Science Project focused on science teaching/learning in the Form 1 to 4 level (ages 10 to 14) and sought to identify problems and difficulties in several areas. Provided in this paper are comments obtained during structured/unstructured interviews (from students, ex-students, teachers, headmasters, science advisers, and inspectors) and observations made by project staff related to process skills/habits. The intent in presenting these comments/observations is not primarily to provide a balanced view of the good and bad aspects of Form 1 to 4 science, but rather to open up problem issues as project staff and others see them. Comments/observations are presented in four sections: (1) views about the teaching of process skills/habits; (2) views about the acquisition of process skills/habits; (3) problems and difficulties of teaching process skills/habits; and (4) problems and difficulties students have in acquiring process skills/habits. Included are eight questions that should be considered in terms of direction for further study, covering such topics as the extent to which teachers are confused over the meaning of the term "process skills," and the identification/development of activities to enhance process habit/skill development. Also included (in an appendix) are discussions, accompanied by flow-charts, of activities/skills associated with three suggested problem-solving categories. (JN)

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LEARNING IN SCIENCE PROJECT

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FOCUS ON PROCESS SKILLS

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The Learning in Science Project is an educational research project undertaken at the University of Waikato under contract to the NZ Department of Education. The project is initially investigating the problems and difficulties of Form 1 - 4 Science (10 - 14 year olds) as a first step to improving teaching and learning.

This paper is one of a set of essays which is an outcome of the exploratory phase of the project. It is our hope that feedback from these essays will assist further to clarify issues and assist us in establishing priorities for the in-depth phase of the project. Any comments our readers have on either the issues involved, or the methodology adopted in these papers, would be most welcome.

Learning in Science,
University of Waikato,
Private Bag,
Hamilton,
NEW ZEALAND.

FOCUS ON PROCESS SKILLS

A WORKING PAPER OF THE LEARNING IN SCIENCE PROJECT

Ross Tasker, Peter Freyberg and Roger Osborne

September 1979

This is one of a set of discussion papers which focus on various aspects of Form 1-4 Science. The paper collates comments and observations, related to the topic of focus, which were obtained during the first phase of the Learning in Science Project. In this phase we were particularly concerned about problems and difficulties in Form 1-4 Science and because of this the paper is biased toward issues as identified by pupils, ex-pupils, teachers, headmasters, science advisers, inspectors as well as by our own observers. Our intention in writing the discussion papers is therefore not primarily to provide a balanced view of the good and bad aspects of Form 1-4 Science but rather to open up problem issues as we and others see them, to a limited but wider audience than the project team.

It is our hope that our chosen readers will be prepared to talk to us about the topic under focus in this paper in terms of the following questions:

- (i) Are the issues we have raised important and central issues which are of general concern?
- (ii) Are there other more basic issues, or other subsidiary questions, about the topic which we have overlooked?
- (iii) Which aspects of the topic could we profitably analyze further in the in-depth phase of the project?
- (iv) What possible solutions to some of the issues raised could profitably be the subject of further study?

INTRODUCTION

The development of process skills and associated habits (Appendix 1) has for some considerable time been an important aim of Forms 1-4 Science in New Zealand (1967, Science for Forms I and II and 1968, Science for Forms III and IV Syllabuses for Schools, Department of Education). This aspect of the study of science has been given more emphasis with the appearance in schools of materials which are outcomes of overseas studies into the teaching and learning of science - Nuffield Junior Science, Science 5 to 13, Scottish Integrated Science and the Australian Science Education Project. The trend has been supported by the latest official syllabus statement, the 1978 Science : F1-4 Draft syllabus and guide which encourages teachers to develop programmes 'which involve maximum activity on the part of students especially in investigating, experimenting, questioning, research and reporting, i.e. programmes where doing science is regarded as just as important as (if not more important than) learning about science.' ¹

Reflecting this approach are the many tasks set by teachers in the Form 1-4 science classroom which require pupils to employ skills and habits. Sometimes these activities emphasise a particular skill, for example classification; however, more commonly, pupils are required to utilise a range of skills in problem solving and investigative situations.

This paper is concerned with the comments that teachers, pupils, school inspectors, science advisers and others associated with science at this level have made to project team members in relation to process skills and habits.² To better appreciate these comments, we have visited many science classrooms and talked to students as they carried out practical work.

¹ The 1978 Science : F1-4 Draft syllabus and guide tends to use the word attitudes in a variety of ways. We would wish to distinguish between those attitudes which refer to feelings towards and interest in science from those more 'scientific' attitudes such as open-mindedness, critical thinking and so on, which have a much greater cognitive component. Attitudes of this second type are often considered as necessary attributes for working in a scientific way and are closely associated with (and often difficult to separate from) process skills. For example, whether a person who has a particular skill chooses to use that skill in a given circumstance is closely related to the scientific attitudes which he holds. For this reason we have tended to use the words 'scientific habits' to describe these attributes.

² FOCUS ON ATTITUDES considers attitudes more related to feelings towards, and interests in, science.

This paper is arranged into four sections:

1. Views about the teaching of process skills and habits.
2. Views about the acquisition of process skills and habits.
3. Discussion about the problems and difficulties of teaching process skills and habits.
4. Discussion about the problems and difficulties pupils have in acquiring process skills and habits.

1. VIEWS ABOUT THE TEACHING OF PROCESS SKILLS AND HABITS

A number of teachers have talked of the important role that process skills and habits have in the learning of science:

- 25/8/2¹ "As far as I am concerned the sciencing process is probably more important than the science facts."
[secondary teacher]
- 24/4/1 "I am not a content sort of person. I prefer the processes of doing things rather than what is actually learnt or what is expected to be known."
[secondary teacher]
- 9/18/2 "I think the science concepts that they are supposed to know are important but I also think that running along parallel with these are all the scientific aspects of learning; how to do research and discover something, and to be independent, ... those things I think are also really important."
[intermediate teacher]
- 21/17/1 Teachers talk not only of the significance of process skills and habits but
25/12/2 also of how they incorporate into their science programmes activities
41/2/3 specifically aimed at developing these aspects of studying science.
- 25/15/1 A few teachers have described how they encourage individuals to develop skills and habits.
- 8/4/3 "If you do get a pupil into those manipulative situations and you see that he is fumbling about then you can do something about it. (What about the inherent fumbler?) Well I think there is that too but, some skills you can get better at with practice."
[secondary teacher]
- 73/4/3 "You can increase a pupil's observation powers by encouraging him to look at things - look past things."
[primary teacher]

¹ Denotes the transcript file from which the quote has been extracted or references a quote which supports the comment made.

To these comments we can add our own observations. We have observed lessons specifically designed to develop particular process skills e.g. classification activities with both familiar and novel objects (finger prints, rocks, etc.) in Form 1 and 2 classrooms to develop classifying and observational skills. In general such lessons have involved relatively basic and specific skills such as those just mentioned classifying, observing and measuring.

Undoubtedly these teachers, whose comments we have recorded and whose lessons we have observed, consider that at least certain process skills can be taught to some, if not all, children.

There also seems to be an increasing awareness in a number of schools we have visited of the need to develop study skills - reading, graphical interpretation and so on.

81/10/1 "One of the things we are looking at is a unit of work on study skills Included in that would be the interpretation of graphs and data and things like that."

[Form 1-7 science teacher]

The above are all positive comments and views about the teaching of process skills. Other comments and views expressed to us, however, suggest that there is a negative side to this aspect of the teaching of science.

We have comment on what is seen as a lack of sensitivity of teachers to skill deficiencies in children.

21/10/1 "Teachers perhaps need to be more aware of the fact that a lot of the skills that they expect their kids to have are lacking, either because of their past or present teaching or because of the kids inability to sit and listen and be interested in what they are doing."

[P.R. Science]

We even have an example.

81/9/3 "I probably don't place very much emphasis on teaching data, handling - mainly because it never occurred to me."

[H.O.D. Science]

This may in part be a reflection of what appeared to us to be confusion over just what process skills are. In discussion with us, some teachers used the term to delineate cognitive activities involved in problem solving; other teachers restricted skills to manipulative aspects of experimenting; and

there were a few who made no distinction in meaning between process skills and concepts and/or attitudes. Teachers who limit their thinking in relation to process skills in the above ways cannot be expected to interpret the 1978 Science : Draft syllabus and guide in the way intended by the curriculum developers.

84/7/2 Whatever the reason, we have received much comment about a general lack of teaching of skills.

Some of the skills which are not always being taught are very basic ones.

17/5/1 "The basic skills in using equipment are not being taught."
[secondary teacher]

12/5/3 "We were never taught how to use the instruments."
[ex-pupil]

63/4/3 "I feel, to be quite honest, we are missing out on the skills - I feel that the one that is most underrated and most underdeveloped is observation."
[primary inspector]

6/12/3 "We pay lip service for instance to skills you see I don't think anyone has looked at this draft syllabus for instance and thought it is a hell of an important for a kid to be able to come up into the sixth form and be able to weigh and measure you have got to make sure you have many activities throughout the 3rd and 4th form where they are going to use that skill so that when they do come up they will have it, you know "
[science adviser]

Other skills which, it is considered, are not being taught are of quite a different nature.

21/10/2 "We are doing a lot of experimental work in the 3rd and 4th form but the kids are not learning experimental method and experimental methodology. We are missing a big thing when we say make lots of practical work and we are doing a lot of practical work but the processes that we are using are not always made obvious to the kids or wanted to be remembered by the kids."
[secondary teacher]

73/3/3 An effect of this, particularly in relation to experimental design, is that
20/20/1 some teachers often set tasks which are beyond the capabilities of many of
21/1/3 their pupils.
20/10/1

21/10/3 "I think that in some cases the experiments are too complicated for them to design even though they may not be really difficult - it is difficult for pupils to understand what they are asked to do."
[P.R. Science]

A specific example of this problem is provided in Appendix 2.

25/19/2 Finally with respect to habits, it is clear that certain teacher habits may in fact actively discourage sound habits in their pupils.

38/2/2 "When it comes to kids questioning me and asking me things - that's where the problems came up because I tended to say 'don't worry about it, it's not necessary to know' because I couldn't answer it myself."

[intermediate teacher]

24/8/1 "If it doesn't work, well that's probably one of the biggest problems. They think it has got to work, and what if it doesn't? How do I explain away something that doesn't work?"

[secondary teacher]

In the paper FOCUS ON EXPERIMENTS we have discussed this problem of the 'right' answer and the 'wrong' answer in more detail, together with the unfortunate effect it can have on children's scientific habits.

The above comments do suggest, and our own observations support it, that while some teachers are aware of the importance of process skills and habits and do try to teach specific skills, many teachers give only indirect attention to the development of process skills and habits. We will consider possible reasons for this later in this paper.

2. VIEWS ABOUT THE ACQUISITION OF SKILLS AND HABITS

A wide range of people, including many of the teachers who now include skill and habit objectives in their science lessons, expressed to us concern over skill and habit deficiencies in many pupils. Some voiced their concern in a general way.

20/1/3 "The skills are not there."

[secondary teacher]

17/23/3 "They haven't even grasped the fundamental scientific procedure of observation, setting up a hypothesis, and testing it somehow, and drawing conclusions to prove or disprove their hypothesis."

[secondary teacher]

Some commented on problems pupils have in understanding what to do.

- 20/16/3 "By the time I'd got to the end of the list [of instructions] they'd forgotten what was at the beginning of the list."
[secondary teacher]
- 25/10/3 "There are really good kids who will pick up a book and follow the instructions straight through but other kids won't follow or can't follow instructions."
[secondary teacher]
- 23/6/1 "Little skills of presentation, being able to identify the right and left hand sides of their pages which I know is assumed but kids get out from underneath it and they arrive [in Form 1] with basic difficulties simple things like down and up and diagonal and middle count 5 lines down and draw a line across the middle of your page [is difficult] which is not really relevant to [science], but in terms of following instructions"
[intermediate teacher]
- Some commented on problems pupils have with collecting and handling information.
- 25/19/1 "They have difficulty with research skills. They have difficulty with knowing how to use material to get information very quickly."
[H.O.D. Science]
- 73/2/3 "The number of kids that look and don't see anything is incredible."
[intermediate teacher]
- 25/12/2 "One skill all of them don't have is being able to look at what is happening with something and put it down in words."
[secondary teacher]
- 15/3/1 "Um ... no ... I don't know a terrible lot [about scientific procedures]. I still don't know how to go about experiments properly and that sort of thing. You just sort of wrote out the methods."
[ex-pupil]
- 17/5/2 "The recording of the work is done in a very haphazard way. This shows no care and no accuracy."
[secondary teacher]
- 41/4/1 "Take observing, for example, like the kids would look at something then they would come and ask us [teachers] rather than sort of searching themselves ... they wouldn't stick at one thing ... by the end of the morning they were really ready to come back [from the field trip] because they'd taken everything at face value rather than looked at it more deeply."
[intermediate teacher]

23/5/3 "The crunch comes when you have to [get pupils] to record or interpret or make notes ... and it is that side of it that we [teachers] find is not developed sometimes it's not there in Form 2 possibly not in Form 4."

[intermediate teacher]

Some commented on problems pupils have using information once it has been collected.

25/19/1 "If you went into my 3rd Form class and gave them a photograph and wanted to know what sort of information you could get from a photograph you would get a pretty good description of what was in the photograph, but very little inference made from what they actually [saw] ... you know inferences made from things that were in the photograph."

[H.O.D. Science]

42/3/2 "I think they find it very difficult to analyse results."

[intermediate teacher]

20/23/1 "Very often they can see the physical results, but drawing conclusions from those results - which requires a bit of thought - that is often quite difficult."

[secondary teacher]

43/10/1 This problem (the ability to draw conclusions) is again discussed further
9/4/1 in FOCUS ON EXPERIMENTS.
23/2/3

Other comment relates to specific skills, for example, measurement or graphing:

23/6/1 "Of the kids in my class, ten couldn't use a ruler ... they operated at the end point rather than the zero mark."

[intermediate teacher]

39/5/2 "Some of them didn't have any idea how to make graphs, how to collect data to make graphs, or how to read them once they'd made them."

[intermediate teacher]

24/4/2 In summary, the comments we have received suggest that there is concern about what process skills are being developed in children. Some people who have taught over the full age range suggest that many skills and habits e.g. careful analysis, open-mindedness, creativity, may actually degenerate from age 11 to age 14. Is this a consequence of developmental factors (e.g. "crystalizing" of abilities) or others operating outside the science classroom (e.g. pressures to conform) or is it a consequence of our teaching of science? For example, is it hard to judge whether the children being described in the following statement are 11 year olds or 14 year olds?

41/26/2 "Most of them are fairly quick to pick things up - you can quite easily miss something but one of the kids will soon point it out - they're pretty sharp ... they will run up and say 'look at that thing doing that' ... and 'look at that one hiding under there' and from that they ask questions you know. It is really good to see them doing things like that ... it shows you how they are looking and thinking about things."

[intermediate teacher]

3. WHAT ARE THE PROBLEMS AND DIFFICULTIES OF TEACHING PROCESS SKILLS AND HABITS?

We have reflected comment earlier that teachers are not always aware of the need to develop skills in children, that in some cases they are not clear what processes and skills should be developed, and that they are not sure how to develop them successfully. If these comments are valid, and we suspect that they probably reflect the situation reasonably well, how do these problems arise?

Many teachers are content orientated and as a consequence many classroom activities are planned to provide factual information or to support concept development. This is another issue covered in earlier working papers of the project (FOCUS ON KNOWLEDGE, FOCUS ON EXPERIMENTS). Teachers who have content directed intentions may be more likely to make assumptions about their pupils' process skills, especially if an activity in a recommended text is considered to achieve their main objective.

8/9/3
42/9/2

Process skills and habits can be difficult to teach.

9/4/1

"The other [difficult] thing would be in the more technical side of science where we're doing experiments and to get children to conclude evidence from the result. There must be a skill in [doing] this and even _____ [a senior teacher] has trouble getting children to do the experiment, see the results and then conclude why something happened."

[intermediate teacher]

23/10/3

"Teaching pupils to do experiments from a skill point of view or from being objective in their attitude or make a control experiment themselves - then that is very difficult."

[secondary teacher]

It is especially difficult if equipment is troublesome:

25/12/1

"Sometimes the skills are a bit difficult. How to use a bunsen. Especially the ones we have got - there are about three adjustments on them. It would be nice if there was a simple bunsen that you just plug in and there was one thing that turned the flame up and one thing that adjusted the air ... but

instead we have got ones that are always breaking down. Something like simple, reliable gear would help."

[secondary teacher]

or the teacher doesn't know how to use it!

79/2/1 "When it comes to using this equipment - I'm lost."

[primary teacher]

Even teaching basic manipulative skills can be difficult with low ability children.

58/2/3 "Many teachers are discouraged from trying because of the difficulty of getting these kids [lower ability children] to cope physically in the manipulation, in the behaviour, let alone in the comprehension."

[secondary science inspector]

From a slightly different perspective, perhaps we have moved too far away from the formal type of experimental work which used to be carried out.

73/6/2 "Sometimes [children] need to be taken away from the very flexible and diverse approach that is being encouraged at the moment and brought back to reality and shown how to write down a stated aim for the experiment and then they need to be taught how to undertake that experiment."

[intermediate teacher]

17/5/3 "I think the failure here is that we don't insist on these basic skills - care of records, care of presentation is no longer insisted upon which I think is a move in the wrong direction."

[secondary teacher]

8/9/3 Another problem we suggest is that although the new Draft Syllabus does emphasise and detail process skills, no clear guide is provided as to how they relate specifically to the work in the classroom, to each other, and to how scientists go about their work. It has been suggested to us that sometimes the teaching of sound scientific habits, for example, are jeopardized because not all teachers really appreciate the purpose of scientific enquiry and really appreciate what sort of activities in children would be considered good science by working scientists.

Traditional resource materials are not always helpful in this regard as they can be oriented, even in experimental work, to the teaching of scientific knowledge and concepts and do not emphasise process skills and habits. Consequently teachers using such texts to plan lessons assume skills and

habits that tend to be lacking in pupils.

Some of the newer written materials available do give a great emphasis to practical work and there are units specifically designed to develop skills e.g. ASEP Skill Builder series. However, the main impression these materials appear to be making is in terms of individualised programmes of work. Their adoption may well reflect a response to mixed ability grouping and a desire to increase practical work rather than a move toward stressing the development of process skills. It is interesting to note that the only programmes we have observed which deliberately set out to provide pupils with an opportunity to acquire a specific skill are teacher inspired and produced.

Another problem is that there is no proven, familiar and readily available procedure for assessing students' process skills and habits. It is therefore hardly surprising that teachers comment on difficulties they have in assessing the skill level of their pupils.

24/11/2

"It is pretty hard in a classroom situation to work out a checklist or some particular way of assessing these particular things."

[secondary teacher]

23/3/2

"In terms of evaluation of these skills I think we could be in difficulty again If there is a range of skills, what are they and how do you rate skills of kids on them?"

[intermediate teacher]

The lack of information of this type may help to explain the virtual absence of skill programmes.

What is clear is that such skill analyses are needed if the skills themselves are to be taught:

73/9/3

"Children need a lot of help in formulating the actual skills of deduction, the skills of analysing, summarising and reaching conclusions - all that needs to be taught to kids - we can't assume that they have already got it."

[intermediate teacher]

4. WHAT ARE THE PROBLEMS AND DIFFICULTIES OF CHILDREN IN ACQUIRING PROCESS SKILLS AND HABITS?

It is clear that where process skills and habits are not taught or encouraged by teachers, it may well be difficult for children to acquire them. It even

seems possible that in such situations children may well lose skills and habits which are considered desirable from a scientific point of view.

42/2/3 However, there are other problems and difficulties too. For example, it is
73/4/1 difficult to acquire a skill if you don't get the opportunity to practise
the skill yourself,

20/20/1 "When we looked initially at filtering - the kids that said they had done it -
said they knew how to fold a filter-paper - but only a few actually did know -
they knew what it was - they had seen it before but they didn't know what to
do with it."

[secondary teacher]

36/9/1 "You have got to feel when you've finished you've achieved something and if
you hadn't been there the results couldn't have been got. It's got to be a
really personal thing when the person involved have enough equipment
for every person at least don't have these big groups of 3 or 4
because somebody always ends up sitting around doing nothing."

[6th form pupil]

or make progress with a novel task if you do not recognise the appropriateness
of a skill you possess.

21/1/1 "I think often they [pupils] still have to be prompted to, say, relate that
section of work to a new section of work in other words to carry the skill
not just when they are talking about something in a new unit you just
have to say this is what you now have to use - the technique you learnt
before. Once they have been reminded of the technique it is usually OK."

[PR Science]

83/9/3 "They were involved in doing the mixtures section and we were working on the
different kinds of methods of separation so I'd given them a variety of
mixtures and said OK you work them out and they didn't know what they were
doing. The processes I had taught them, that they had done in a structured
way, they didn't use them in a structured way in their own experiments."

[F1-7 teacher]

One set of comments which give cause for concern are those that suggest that
only a very few pupils ever become skilled in some tasks.

21/10/2 "There are not many kids in the 5th form who could design an experiment very
well ... there are not a great number of pupils in the sixth form who could
do it an awful lot better designing an experiment is even difficult for
7th formers."

[PR Science]

20/1/1 "There is something wrong somewhere - because we have to repeat each and
everything each year."

25/19/2 "but that [writing reports] is not peculiar to the 3rd and 4th form, and not science either. You have to do the same thing [teach them how] with the sixth and seventh form."

[H.O.D. Science]

COMMENT

The teaching and learning of process skills and associated scientific habits involve a wide range of objectives across the full spectrum of psychomotor, cognitive and attitudinal fields. It is clear therefore that few overall generalisations can be made. However, it would appear that some teachers have developed and are developing specific programmes to teach specific motor skills. Concern has also been expressed about the lack of teaching and student ability in certain cognitive skills associated with the scientific process e.g. planning an experiment, drawing conclusions, recording and analysing data. It would appear that for such skills specific teaching programmes tend not to have been developed; rather it is hoped some of these skills will "rub off", so to speak, from experimental work which, incidentally, is often primarily orientated to teaching or discovering scientific knowledge. Finally, only very infrequent comment has been made by teachers about scientific habits such as open-mindedness, critical thinking, and so on. Do teachers see these as completely beyond either their own or their pupils' capabilities? Or, are they considered such general skills as either to be acquired without specific teaching or else to be not worth mentioning?

In terms of directions for further study in relation to this focus, the paper raises a number of questions.

1. To what extent are teachers confused over the meaning of the term "process skills"?
2. What specific problems and difficulties do Form 1 to 4 pupils have with specific process skills and habits?
3. Can classroom activities and teacher actions be identified and developed which enhance specific process skills and habits in children aged 10 to 14 years?
4. Can effective instruments be developed to measure specific process skills and habits, and can such instruments be of a type readily utilisable by teachers in classroom situations?

As indicated earlier, there are teachers who are grappling with the issues raised in these questions. How can their work assist the work of the project and how can we best support their efforts? Should we

1. survey teachers to establish the extent of confusion relating to what is meant by the term process skills? Such information could then be used to produce a statement for teachers and teacher trainers.
2. work in science classrooms with pupils as they carry out activities set by their teachers with the view to illuminating specific difficulties that pupils have? Then explore with teachers and pupils strategies for overcoming such problems. We have the time to do this, teachers don't.
3. examine in depth those few existing programmes where teachers are attempting to establish specific skills and habits? Do the pupils who have experienced such programmes show an enhanced ability to grasp science content (concepts, relationships)?
4. use existing and/or develop assessment procedures to measure specific process skills and habits, especially those listed in the 1978 Science: Fl-4 Draft Syllabus and guide?

Strategy 2 is in sympathy with the philosophy of the project and would, we believe, provide rich data and greater insights than currently available in published research. However, the economics of the classroom may well demand that less sensitive instruments also be developed. These could be of great value to teachers especially if some basic framework of expected skill and habit development existed.

What do you think?

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We are grateful to all those people who so freely talked to us about Fl-4 Science. We also wish to thank the teachers and pupils who so willingly allowed us to join them in their classroom activities.

PROCESS SKILLS AND SCIENTIFIC HABITS

One of the problems in discussing process skills and scientific habits is deciding what is meant by these terms.

When scientists tackle various problems they employ a variety of different procedures. These, collectively, are frequently referred to as the "scientific method". In reality, however, scientists rarely follow any stereotyped course of action. What they do is in fact determined by the nature of the problem being investigated and the personality of the scientist involved. Thus there is little reason to restrict one's view of scientific activities to any single common approach. In short, there are as many scientific methods as there are individual scientists and unique problems.

On the other hand, we accept that some form of the classical approach popularised in the seventeenth century by Gallileo¹ is almost always present in scientific research because it works so well so much of the time. Such an approach involves a cycle of activities.

What is common to scientists is rather the attitudes and work habits which they bring to the task. Not all of these are peculiar to science but, considered collectively, these attributes probably characterise an individual as a scientist or an activity as science.

Implicit in the above comment is the primary objective of all science activity - to find answers to specific problems. Such activities are appropriate in the learning of science and indeed are encouraged in the 1978 Science: Draft syllabus and guide. It seems to us that three types of problem-solving activities are associated with the learning of school science:

I. Acquiring knowledge by investigating the real world.

This can range from making simple observations to conducting sophisticated controlled experiments.

II. Acquiring knowledge by using appropriate reference material.

This is certainly not an activity unique to science but one which is a significant component of the activities of many scientists.

¹ Comment on this can be found in HARVARD PROJECT PHYSICS, PROJECT PHYSICS COURSE, New York: Holt, Rinehart Winston, 1971 (Text 1, section 2.10, p.59).

III. Using established scientific knowledge and theories to solve problems and make predictions.

One of the main outcomes of scientific studies is to produce theories so that deductions and/or predictions can be made without continually resorting to experimentation.

The above three types of activity are all found in schools. The first is exhibited primarily in experimental work. Often this activity is restricted because the problem to be investigated, and the procedure whereby it will be investigated, are chosen solely by the teacher. The second type of activity relates more to project type work. Again, the problem and method of obtaining information may be chosen simply by the teacher, thus limiting the range of skills developed by pupils. In the formal class teaching situation little opportunity then exists for the pupils to develop any associated skills or habits. The third type of activity relates to solving theoretical problems where pupils are required to produce a result through the application of scientific theory. The solving of problems in physics and chemistry most clearly exhibit this particular activity, and mathematical skills are often required.

In figure 1 five major components of problem solving are detailed. Of course, the solving of problems rarely follows such a tidy sequence as that set out in the diagram but sooner or later in the process all the five types of activity are implicitly or explicitly involved. Some of the scientific habits associated with problem solving are also shown, in conjunction with those activities which they tend to influence most directly.

Figures 2, 3 and 4 attempt to identify, on two levels, activities and skills associated with the three suggested categories of problem solving employed in school science.

- I. Acquiring knowledge by investigating the real world (figure 2).
- II. Acquiring knowledge by using appropriate reference material (figure 3).
- III. Using established scientific knowledge and theories to solve problems and make predictions (figure 4).

At the more general level, as in figure 1, five activities are identified, while at the more specific level particular skills associated with the various activities are indicated.

Figure 1: Activities involved in problem solving (boxes) and the habits by which they are influenced.

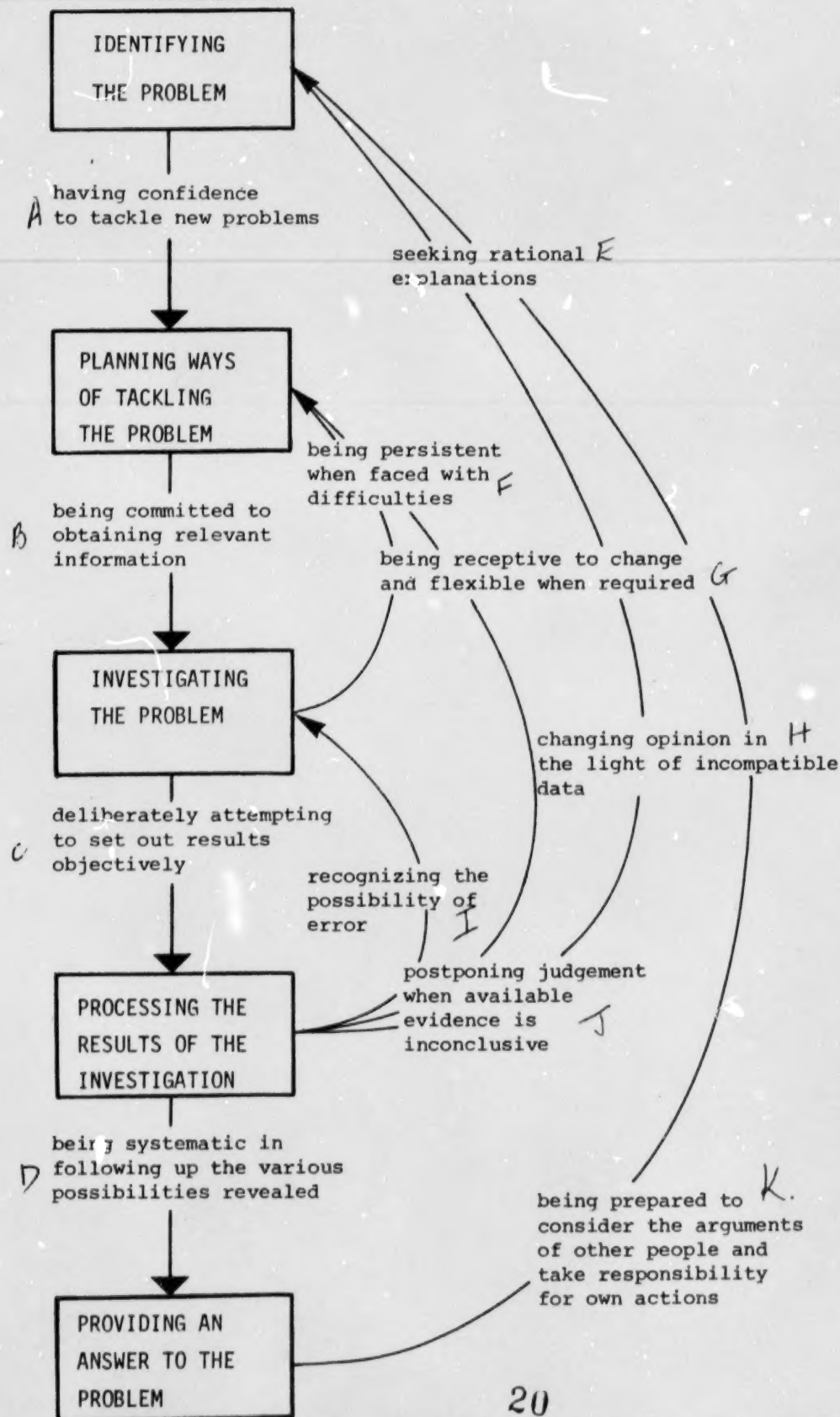


Figure 2 Activities and skills involved in acquiring knowledge by investigation of the real world.

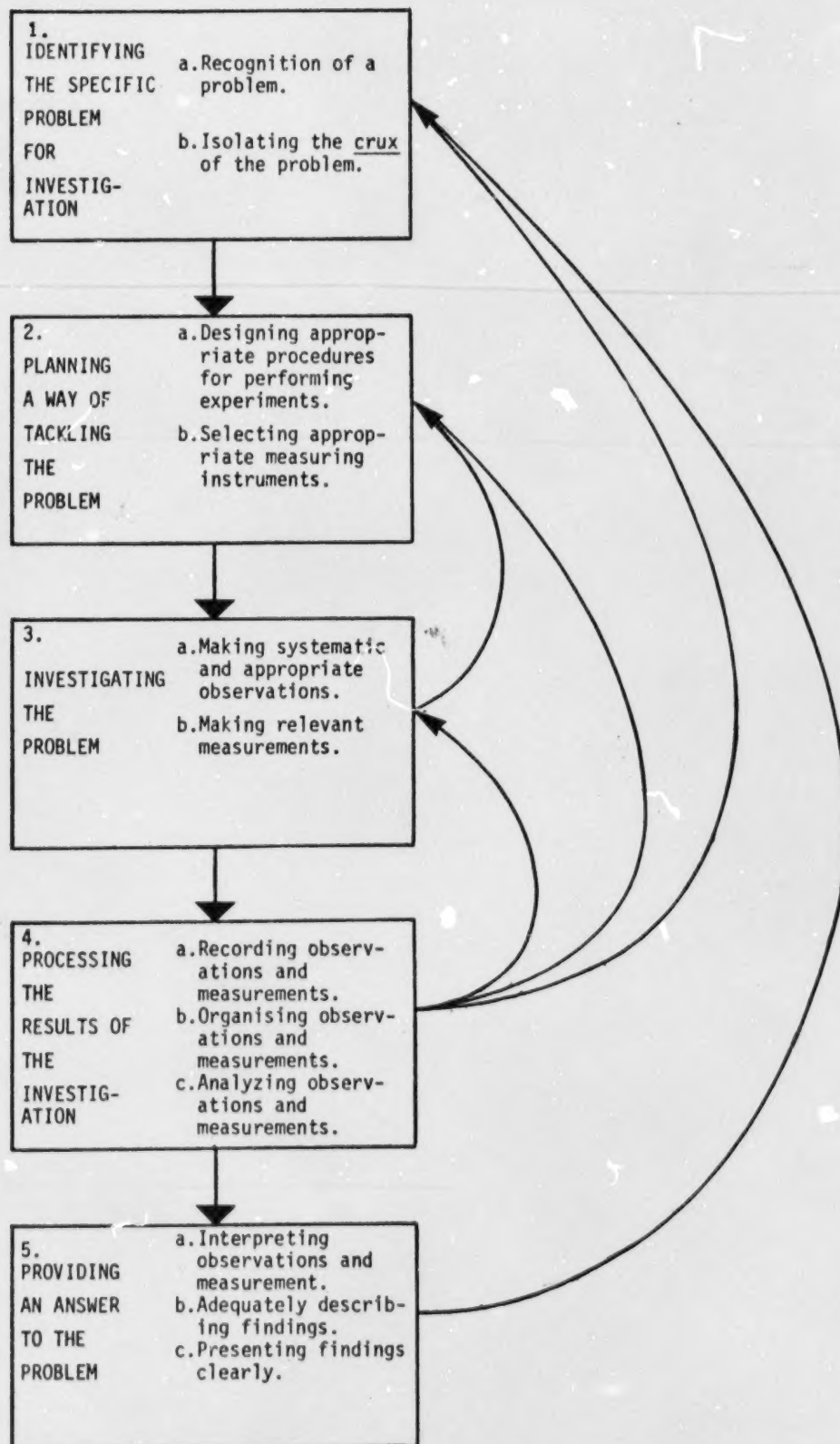


Figure 3

Activities and skills involved in acquiring knowledge
by using appropriate reference material

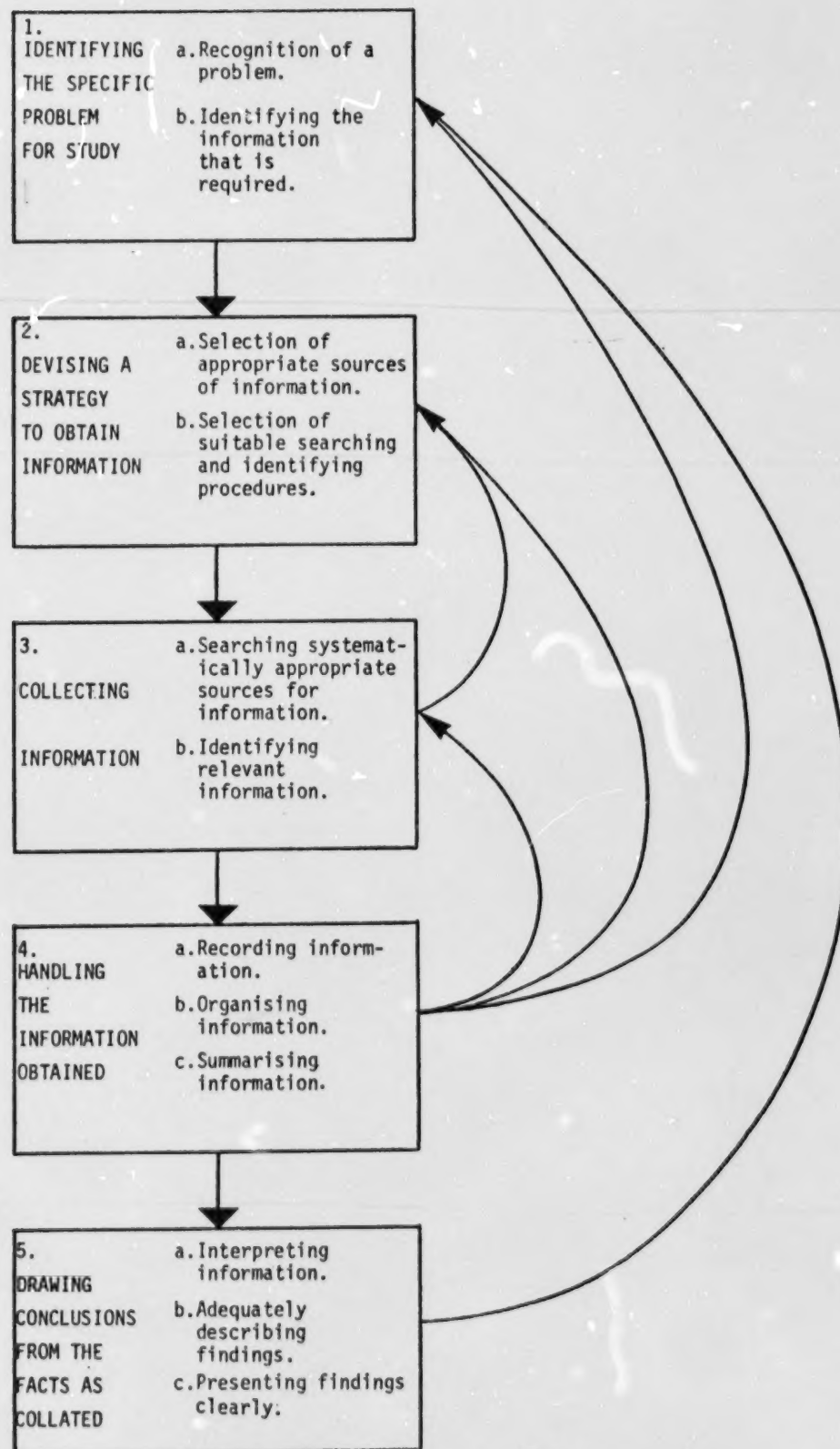
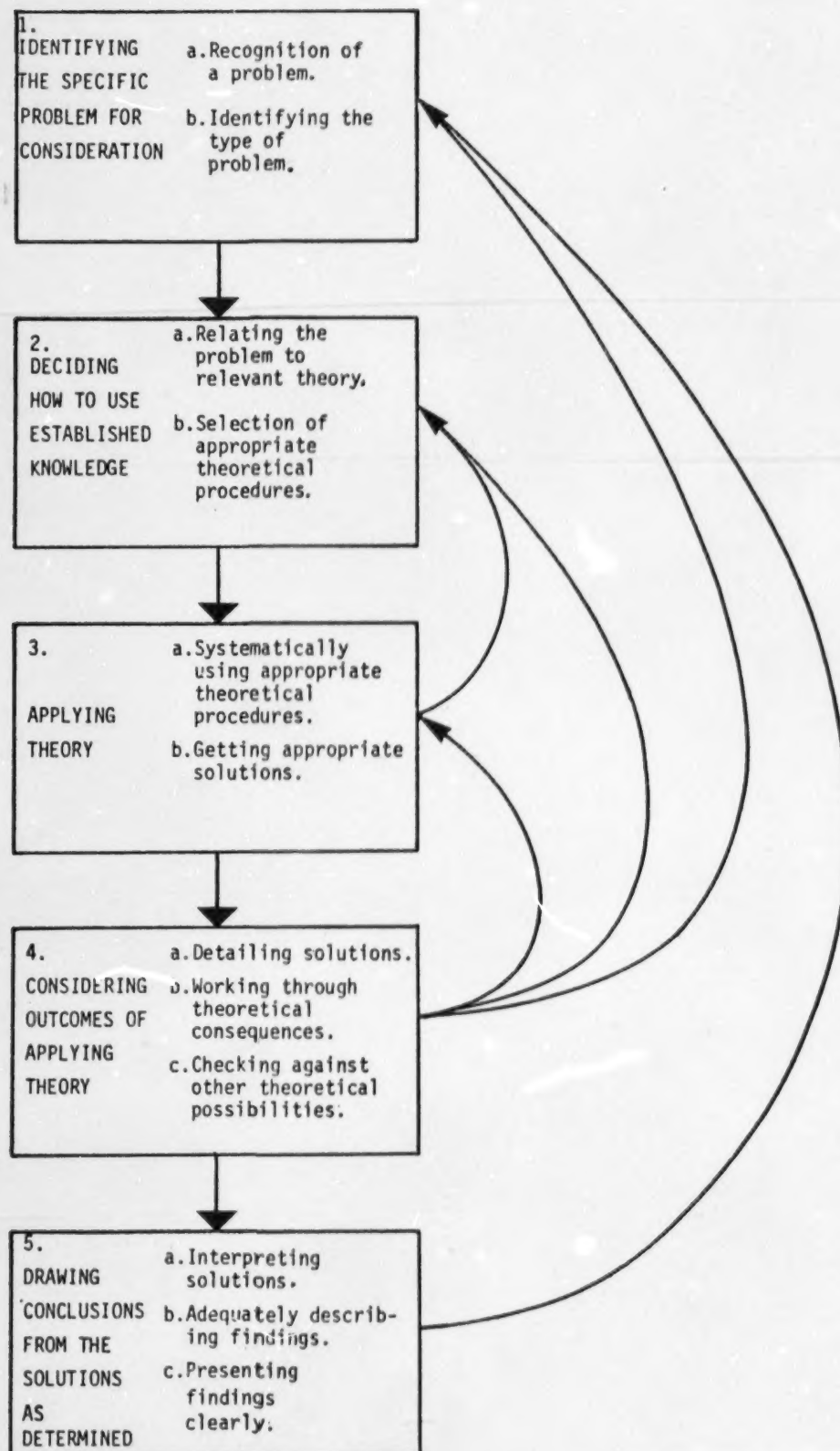


Figure 4 Activities and skills involved in using established scientific knowledge and theories to solve problems and make predictions.



This appendix has been developed, attempting to work out for ourselves what is implied in the use of the terms "process skills" and scientific "attitudes" (i.e. habits excluding feelings towards, and interest in, science) in the 1978 Science: Draft syllabus and guide. We wonder if teachers find this aspect of the Draft syllabus difficult to understand and implement? Do teachers find the words used in the Draft syllabus in relation to skills and habits particularly meaningful and therefore useful in terms of lesson preparation and pupil assessment? Finally, do the teachers reading this appendix consider that our attempt to establish a meaningful picture of skills and habits as they relate to school science makes more sense? We think it does, but are anxious to receive comment from teachers and others.

APPENDIX 2

THE COMPLEXITY OF THE EXPERIMENTAL DESIGN

22/2/2

"In the 3rd and 4th form I put a lot of effort into trying to devise experiments which are simple enough so the kids can see what is supposed to be going on - sort of one variable - simple enough so the kids can see what is going on and a lot of them have dreadful trouble afterwards. They have a tremendous time - they enjoy doing it but afterwards they haven't learnt anything it brings to mind one [experiment] I did this year which was far too difficult for my 4th form - I did it last year with a clever 4th form and it went well. It is boiling up saliva and putting starch with it and testing it later with Benedicts to see if there was any starch present - then doing the same thing with an unboiled sample and it worked beautifully there was sugar in the unboiled sample where the starch had been broken down and none in the boiled sample. But the kids just didn't know what they had done - with all the different colours turning up, with boiling things, and not boiling things - it was just too much I found ... You just have to take it so simply in the 3rd and 4th form and I think some of them don't seem to be able to grasp the ideas behind science certainly from a practical point of view."

[secondary teacher]

This teacher's view seems to be supported by a pupil's view:

15/11/2

"I found the 4th form experiments...I really like those...you had these little trays and holes and you dab a bit in each....I didn't like those because you don't know what you are doing...you have a little bit of green here...a little bit of red there...what's that?...you know?"

[ex-pupil]